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Human Exposure Assessment of Indoor Dust: Importance of Particle Size and Spatial Position

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Stapleton et al. (2012) reported that

serum Σ pentaBDEs [sum of pentabrominated diphenyl ethers 47, 99, 100, and 153] were significantly correlated with both handwipe and house dust Σ pentaBDE levels, but were more strongly associated with handwipe levels ($r = 0.57$; $p < 0.001$ vs. $r = 0.35$; $p < 0.01$).

Here we propose an explanation for this phenomenon.

Toxicants are not distributed homogeneously in dust according to particle size; particle size distribution of settled dust varies with its spatial position. Thus, distribution of polybrominated diphenyl ethers (PBDEs) will vary with the particle size of dust and the spatial position of settled dust, as well as the location of PBDE sources, such that PBDE levels in settled dust on the floor will be different from those of settled dust above the floor (Björklund et al. 2012; Wu et al. 2010). Because of the spatial position of particles, humans are likely to be exposed only to particles of specific sizes. In addition, exposures to children and adults may be different because particles to which children and adults are exposed often have different spatial position and particle size distribution (Cao et al. 2012; Ruby and Lowney 2012). In addition, the reliability of human exposure assessments may be substantially influenced by between-room and within-room spatial variability of PBDE concentrations in indoor dust (Muenhor and Harrad 2012).

As reported in many other studies, Stapleton et al. (2012) reported that for dust sampling, they vacuumed “the equivalent of the entire floor-surface area for the room ... by gently drawing the crevice tool across the top of all surfaces,” and they selected fractions $< 500 \mu\text{m}$ for their analysis. Only a few studies have demonstrated that particles $> 250 \mu\text{m}$ are not appropriate for risk assessment of human exposures (Cao et al. 2012). Thus, if the dust samples from the house and from handwipes have different particle size distributions and are from different spatial positions in the indoor environment, it is inevitable that the PBDE levels in handwipes and house dust will be different and the correlation between PBDE in human serum and house dust will be weaker.

For human exposure assessment, we propose that indoor dust samples to be analyzed

should be from relevant spatial positions and of specific particle size. By improving sampling strategies, we can obtain more accurate results and the correlations between PBDEs in human tissues and indoor dust will be much more accurate. In addition, settled dust should be sampled separately for adults and children.

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Human Exposure Assessment of Indoor Dust: Webster and Stapleton Respond

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We agree with Cao et al. that methods for sampling dust are insufficiently uniform between research groups and can be improved (Allen 2008a; Harrad et al. 2010). By using refined dust sampling methods we should be able to reduce exposure measurement error, likely random, leading to increased

associations with exposure biomarkers. We have conducted several studies on polybrominated diphenyl ethers (PBDEs) investigating methods of dust sampling, the relationship between dust concentrations and potential sources of PBDEs, dust concentrations and biomarkers of exposure, and the use of handwipes as an intermediary step (Allen et al. 2008a, 2008b; Stapleton et al. 2008; Watkins et al. 2011, 2012; Wu et al. 2007). It is worth noting that dust sampling for environmental chemicals can have several purposes, including exposure assessment and characterization of sources. Dust sampling is also subject to a number of practical constraints such as sampling logistics and the requirement for sufficient mass of dust for adequate quantification of target compounds. We believe handwipes represent a more biologically relevant measure of indoor exposure for PBDEs than dust sampled from the floor of a room. Handwipes may also represent exposure experienced by direct contact with PBDE-treated sources. In addition, handwipes may integrate exposure across multiple micro-environments (Watkins et al. 2011, 2012). We agree that the dust particle size is likely to play a role in exposure to PBDEs, and this factor has received relatively little attention in the past. Recent work by Weschler and Nazaroff (2010) suggests that, on average, semivolatile organic compounds (including relatively more volatile pentaBDE congeners) are distributed in a room between air, dust, and surface films roughly as expected by equilibrium partitioning. The levels of pentaBDEs in all of these sampling media are therefore likely to show associations with body burden, although refinement of sampling methods may improve associations. The situation may be different for BDE-209, the main constituent of decaBDE that is essentially non-volatile at room temperature. It may escape from products via friability rather than volatilization (Webster et al. 2009). The particle size distribution of BDE-209 in dust may be different than that of pentaBDEs. Finally, researchers and risk assessors estimate exposure to chemicals in dust by multiplying dust concentrations by highly uncertain exposure factors for dust ingestion (U.S. Environmental Protection Agency 2011). Additional research on dust ingestion factors is needed.

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